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SUMMARY OF INVENTION

Technical Problem

[0026] The problems with the related-art technology are that it is not possible to achieve optimality or not even sub-optimality of operation. Since there is no information about future load demand, renewable generation and blackout duration (or blackout duration probability function), optimal charge/discharge patterns and generator on/off commands cannot be calculated. In order to derive optimal decision, prediction of future development is necessary. More concretely, following problems I to IV should be considered to derive the optimal decision.

[0027] Problem I: The fuel consumption of an energy supply system equipped with a battery and a generator with PDE is high. Therefore, the fuel consumption of the generator must be reduced as much as possible. Without the above-described comprehensive type of prediction and optimization, wrong charging/discharging and generator decisions may be taken which lead to increased fuel consumption.

[0028] The related-art technology has often a switching logic which is priority based as described in [NPL1]. However, with this type of technology, even if priority based switching is better than some other approaches, optimality cannot be guaranteed in most of the cases. Low loading of the generator leading to a waste of fuel cannot be avoided in the general case. The related-art technology often works with a fixed upper charge limit and a fixed lower discharge limit for the energy storage. It can be shown analytically that there are a lot of cases where only suboptimal operation and not optimal operation can be achieved with this technology.

[0029] In order to minimize the fuel consumption of the generator with PDE (monotonically decreasing), future load, future renewable generation (if available), and blackout duration (if there is an unreliable grid connection) is necessary to know, in order to guarantee that the generator runs always in its most efficient mode and unnecessary battery charging is avoided. The related-art technology that does not provide this functionality needs prediction technology and special optimization and control method. Without prediction of load, generation and blackout duration and without time variant charge and discharge limits, it is not possible to determine the optimal charge/discharge cycle for the battery and the optimal generator start/stop command.

[0030] Problem II: The cost (or TCO (total cost of ownership)) of an energy supply system equipped with an energy storage and a generator with PDE is high. Therefore, the running cost of the system should be reduced. Cost optimization is strongly related with the fuel consumption minimization.

[0031] Problem III: Guaranteeing reasonable number of PDE generator starts.

[0032] Without sophisticated prediction, cost/fuel optimality and reasonable number of PDE generator starts, both, cannot be guaranteed at the same time.

[0033] Problem IV: Blackout probability or prediction of exact blackout start time does not help to find the optimal charge/discharge cycle for the battery and the optimal generator start/stop command.

[0034] A lot of previous proposals such as [PL4]-[PL9] related with blackout events deal with prediction of the start time of the blackout, or with the blackout start probability of future time instants. However, this type of prediction is not needed and does not help to improve efficiency of this type of energy supply system. If a blackout happens, the energy storage can automatically take over to feed the load for a certain period, while the parameter of optimal future charge/discharge pattern for the energy storage and the parameter of optimal future generator starts can be only be computed (exactly or approximated) if some kind of knowledge about the blackout duration is available.

[0035] Problem IV is addressed by a method to predict the blackout duration probability function. This means that not the single blackout duration is predicted, but different blackout durations are given a probability of occurrence and the optimization method tries to derive energy storage charge/discharge commands and generator off/on commands which satisfy different blackout durations.

[0036] An exemplary object of the present invention is to solve the problems of the related-art technology and to provide an energy management method and system which can reduce cost, fuel consumption of the generator and keep generator wear within reasonable bounds.

Solution to Problem

[0037] According to one exemplary aspect of the present invention, an energy management method for an energy supply system which includes at least an energy storage, a load and a generator with power dependent efficiency includes: calculating two time variant parameters indicating a discharge lower limit and an upper charge limit, respectively, of the energy storage, based on optimization using different kinds of prediction; and controlling, in a real time manner, charging and discharging of the energy storage and operation of the generator, with a certain priorities given to various power sources, such that state of charge of the energy storage is controlled within a region between the discharge lower limit and the upper charge limit.

[0038] According to another exemplary aspect of the present invention, an energy management system for an energy supply system which includes at least an energy storage, a load and a generator with power dependent efficiency includes: prediction means for performing differ-